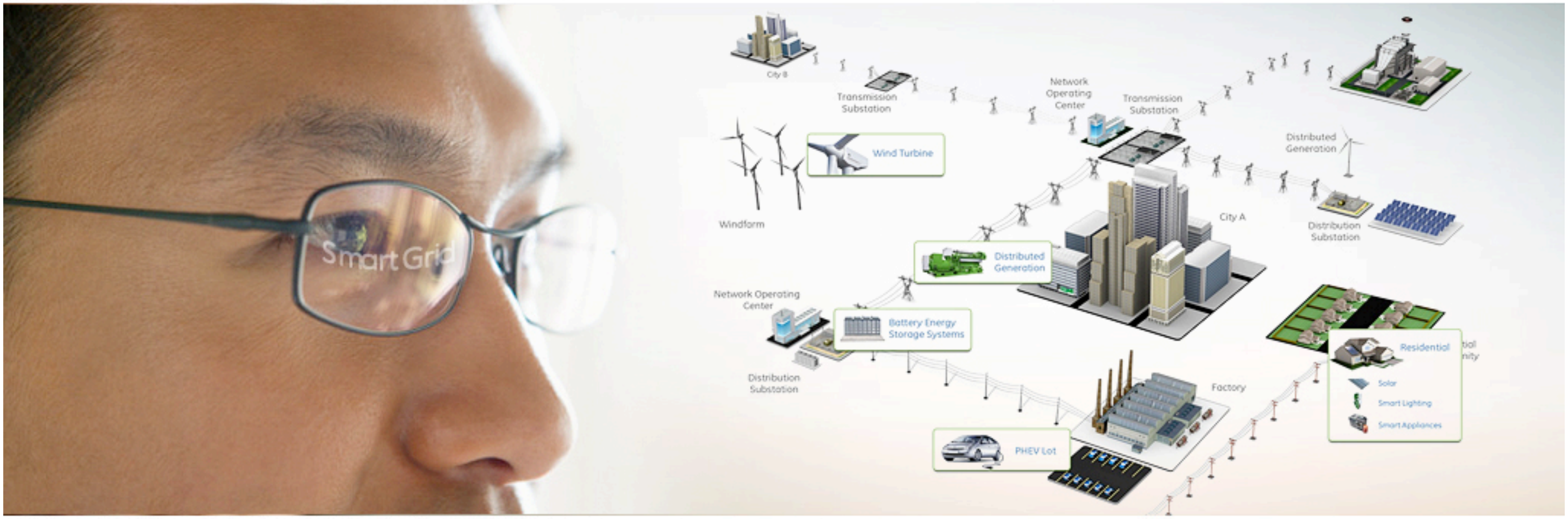

A Holistic Microgrid Energy Management System for Improved Energy Efficiency and Renewable Integration

Bobby Sagoo, GE Digital Energy

Microgrid Symposium – Santiago, Chile
September 2013

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Approach / Technologies

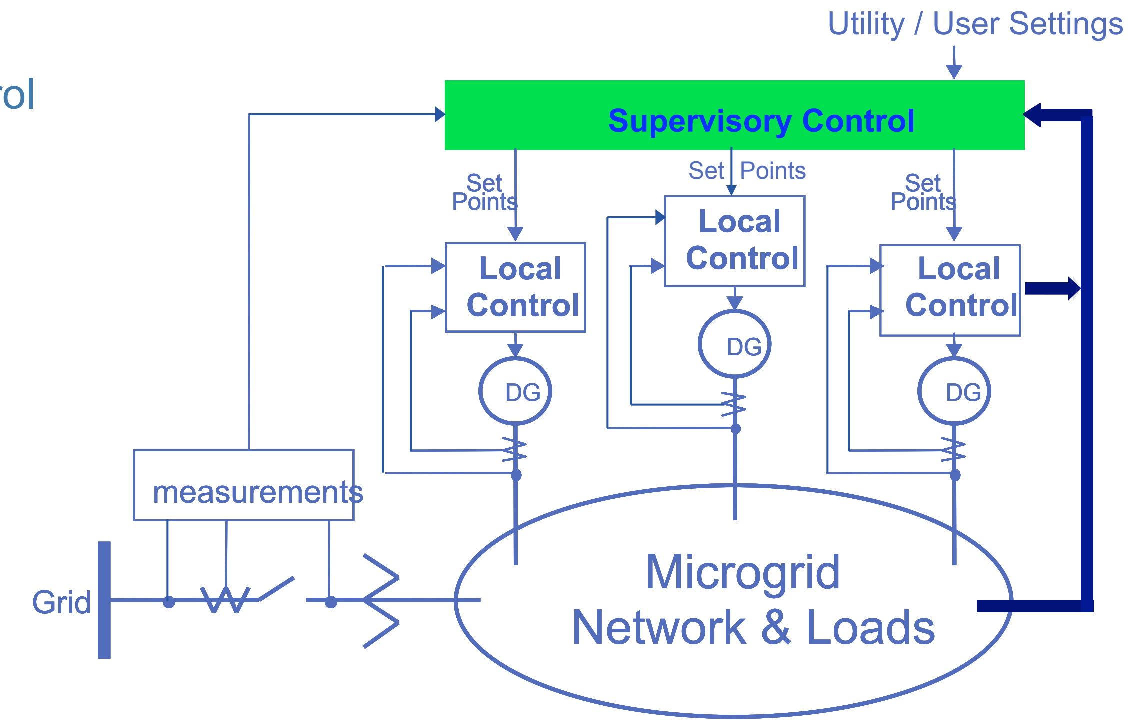
1. Supervisory Control
2. Holistic Energy Approach
3. Optimal Dispatch
4. Demand Optimization
5. IVVC
6. Communication

Microgrid Control Approach

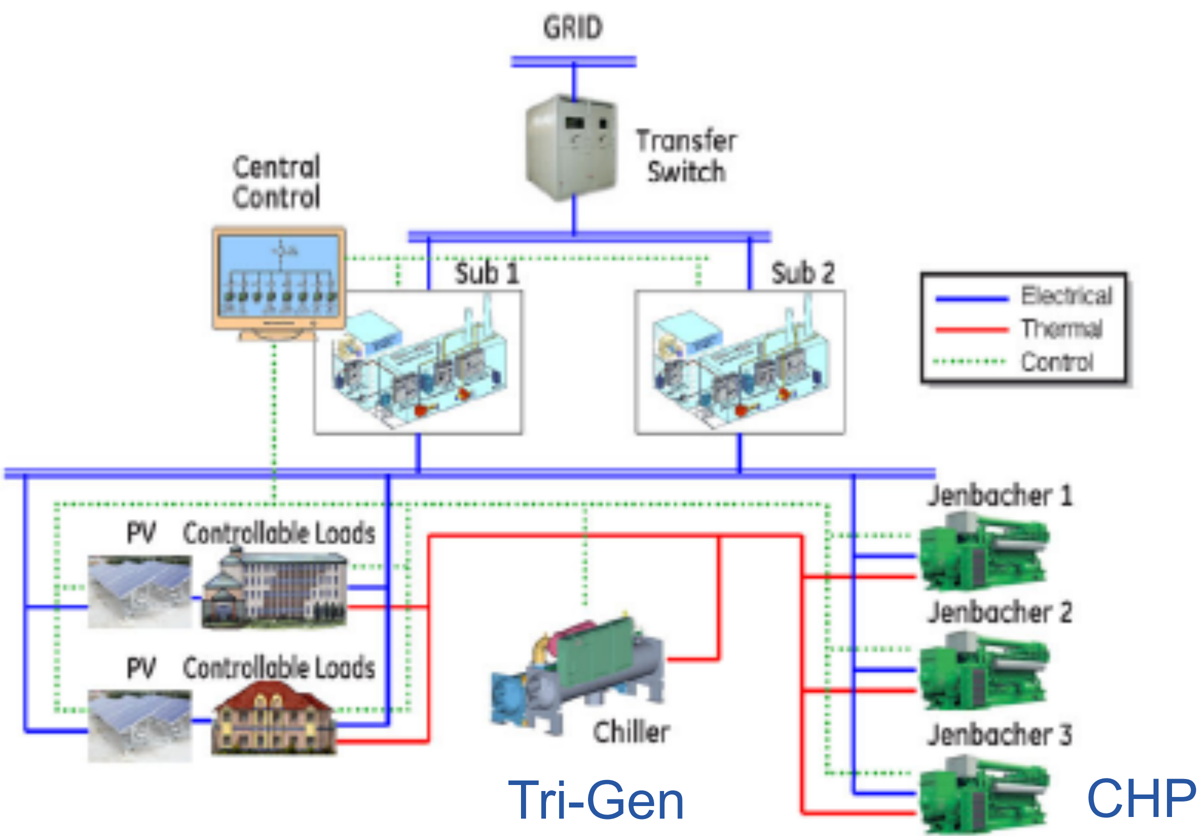
Supervisory Controls

- Optimal Dispatch to optimize electrical and thermal performance and cost
- Manage feeder connection to bulk grid
- Manage renewable intermittency
- Demand Optimization
- Integrated Volt / VAR Control

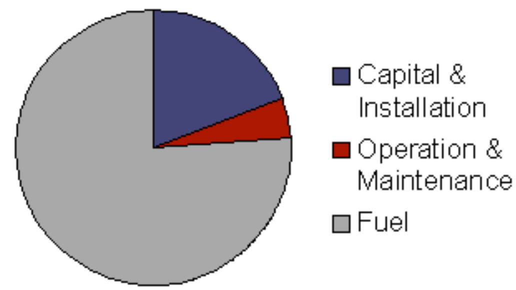
Power, Frequency, Voltage, VARs



Holistic Energy Viewpoint



Total COE ($/kWh) = C&I + O&M + F



http://www.energy.ca.gov/distgen/markets/electricity.html

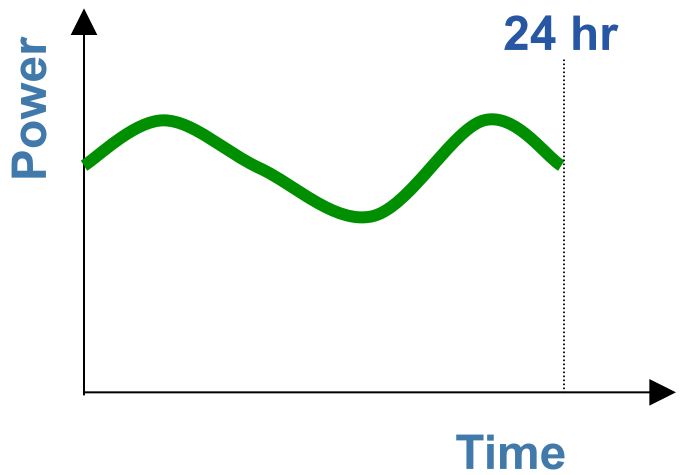
Electrical Dispatch with Tri-Gen Optimization
- Overall Energy Efficiency > 70%

3.3 Optimal Dispatch

The process of allocating the required load demand between the available resources such that the cost of operation is minimized.

The optimal dispatch algorithm implements *Model Predictive Control* using:

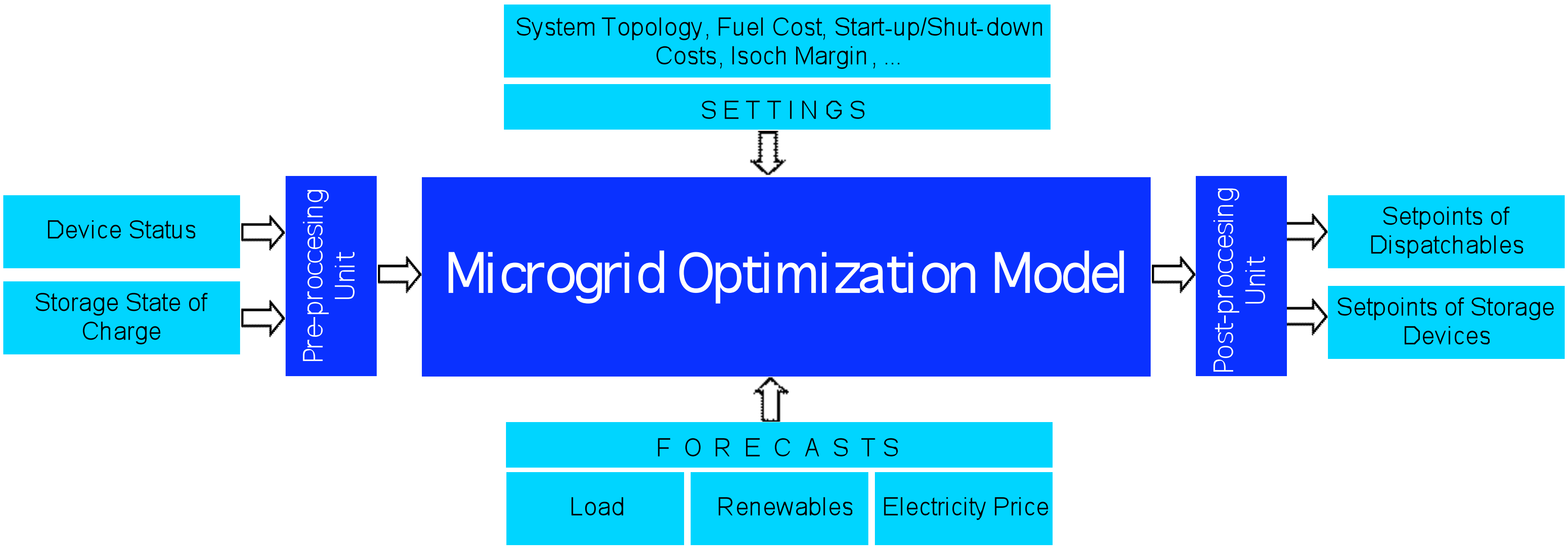
- **Load** forecasts
- Generation forecasts (dispatchable and non-dispatchable)
- and **Stored Energy**



Additional optimization constraints include:

- Unit Commitment, Start/Stop
- Min/max power/thermal output
- Generator Efficiency, Storage Efficiency
- Speed to ramp up/down output
- Electricity–to-thermal ratio in Combined-Heat-Power (CHP) source
- Market price of electricity (if connected to the utility grid) and fuel for DER Assets

Optimal Dispatch



Demand Optimization

1. Emergency Load Shedding
2. Load as a Resource
    - Building Energy Management
    - Backup Gensets

Emergency Load Shedding

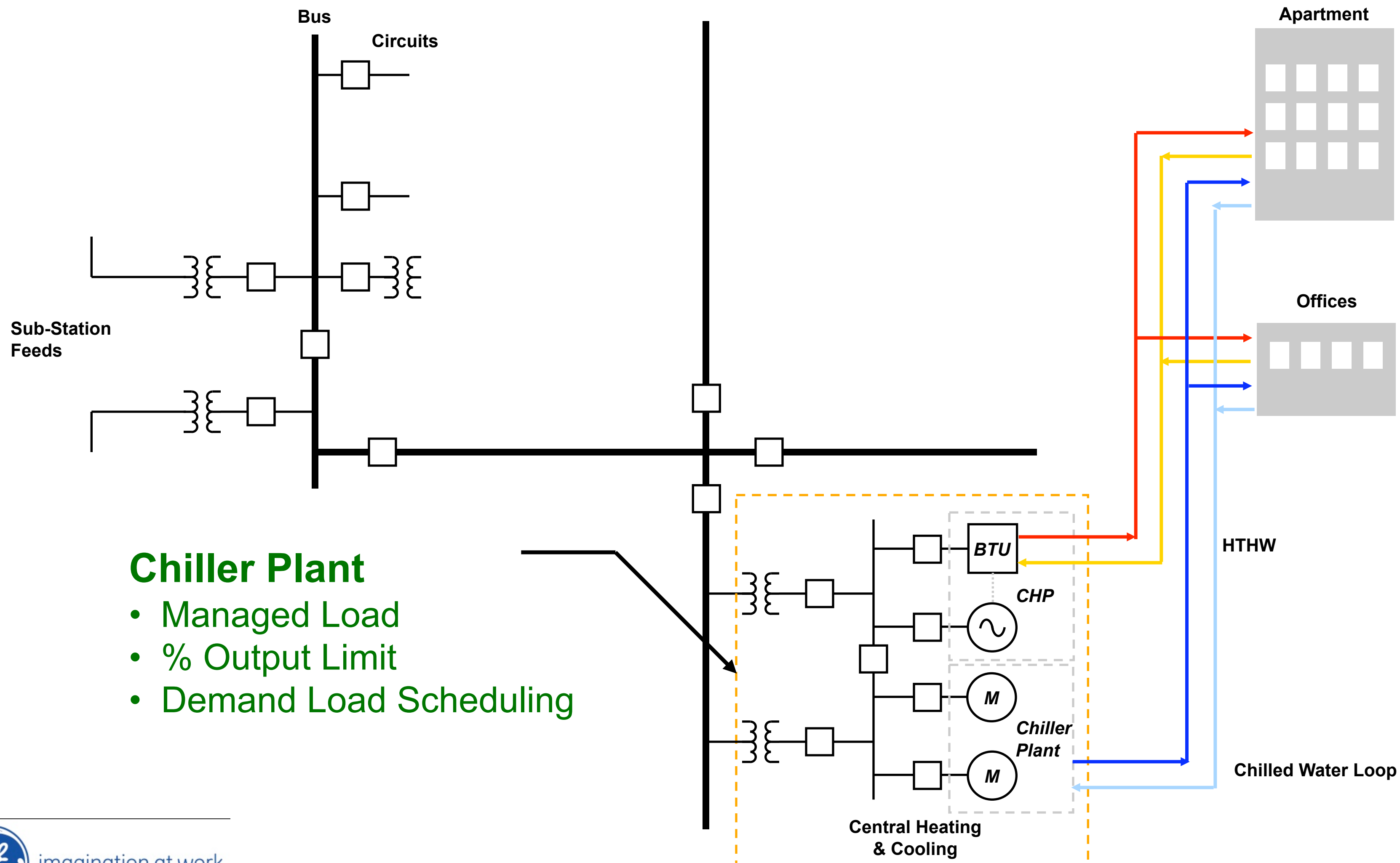
An intelligent scheme that will arm the required amount of load to be shed in order to maintain system stability

- Prioritization of loads & generation
- Dynamic load shedding based on potential generation deficit
- Dynamic generation shedding based on potential generation excess

Shedding may be triggered by a fast message sent over communications or by a local measurement of frequency

BEM: Heating/Cooling Demands

Thermal Load Management & Demand Limit



Chiller Plant

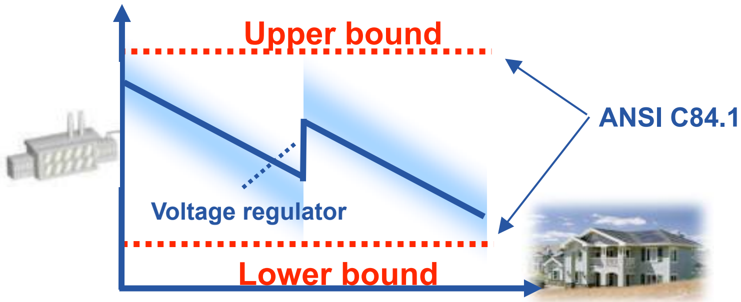
- Managed Load
- % Output Limit
- Demand Load Scheduling

Integrated Volt / VAR Control (IVVC)

MG Distribution Grid Optimization

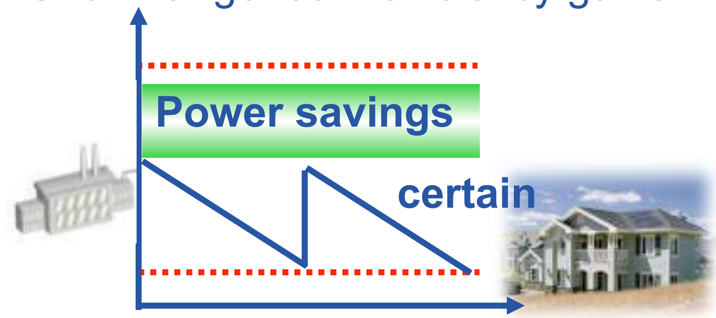
Status quo

Uncertainty **=** inherent waste



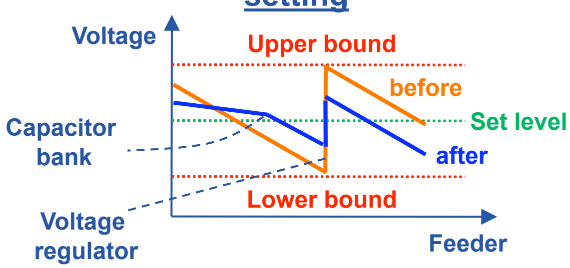
Possible tomorrow

Grid intelligence **=** efficiency gains

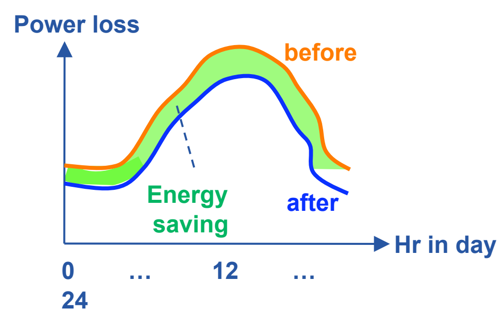


*Optimize **Voltage** and **VAR** profiles to minimize distribution losses and manage load*

Flatten voltage around a desired setting



Power loss minimization



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Communication

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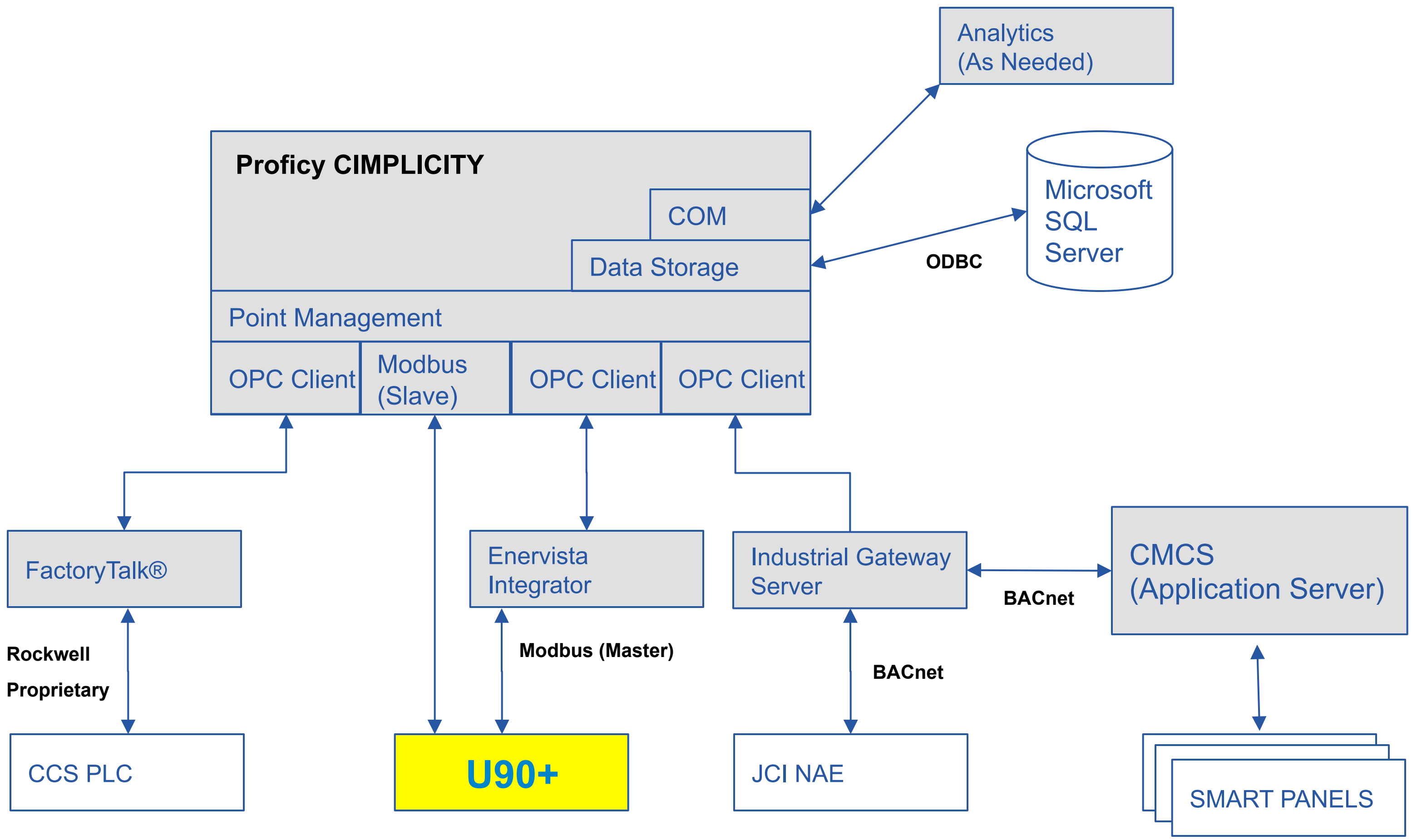
Communications & Cyber Security



Case Study: 29 Palms Microgrid

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Overview

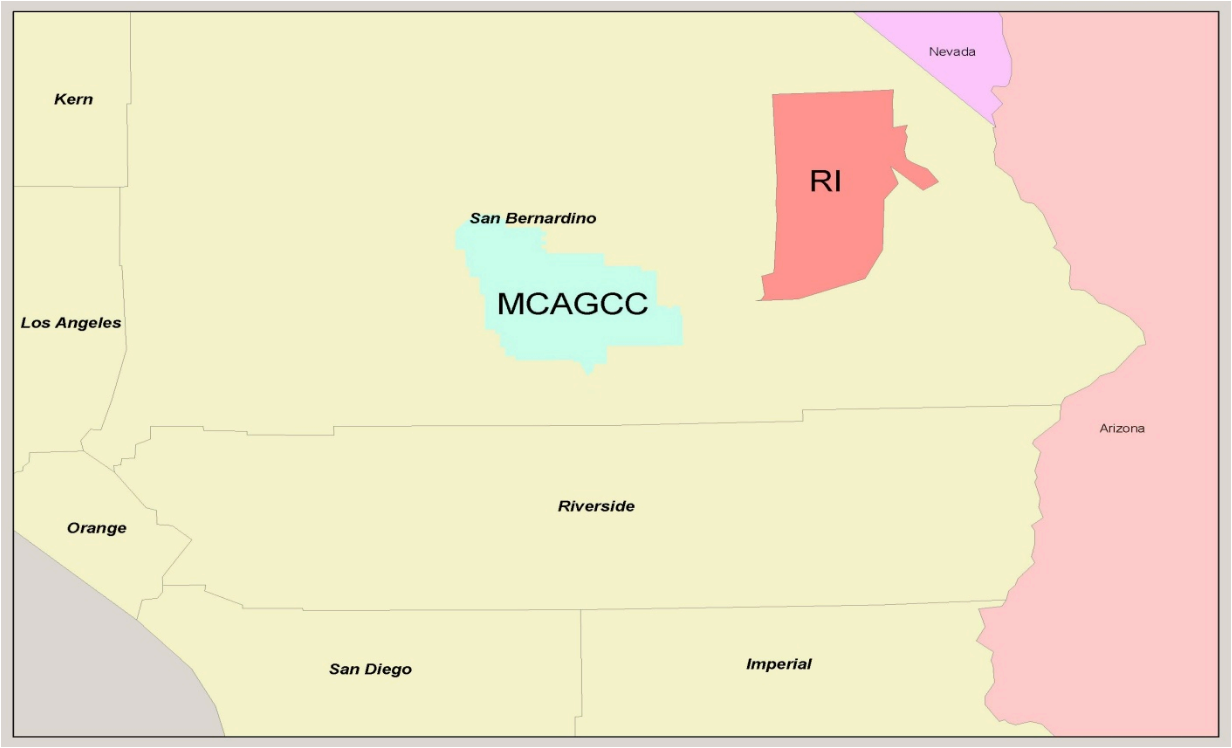
Department of Defense (DoD):

- manages > 577,500 buildings and structures
- worth $712 billion
- located on more than 400 installations in the United States

- spends $3.5 billion per year on facility energy consumption
- is the largest single energy consumer in the Nation
- has policies to:
  - increase energy conservation,
  - reduce energy and water demand, and
  - increase the use of renewable energy
  - reduce emissions

MAGTFTC / MCAGCC

Marine Air Ground Task Force Training Command / Marine Corps Air Ground Combat Center



Objective:

Enhance and demonstrate the advanced microgrid control technologies at a suitable DoD installation to improve energy efficiency and increase energy security

ESTCP Project Purpose:

1. Execute the technology demonstration to validate the technology's performance and expected operational costs.

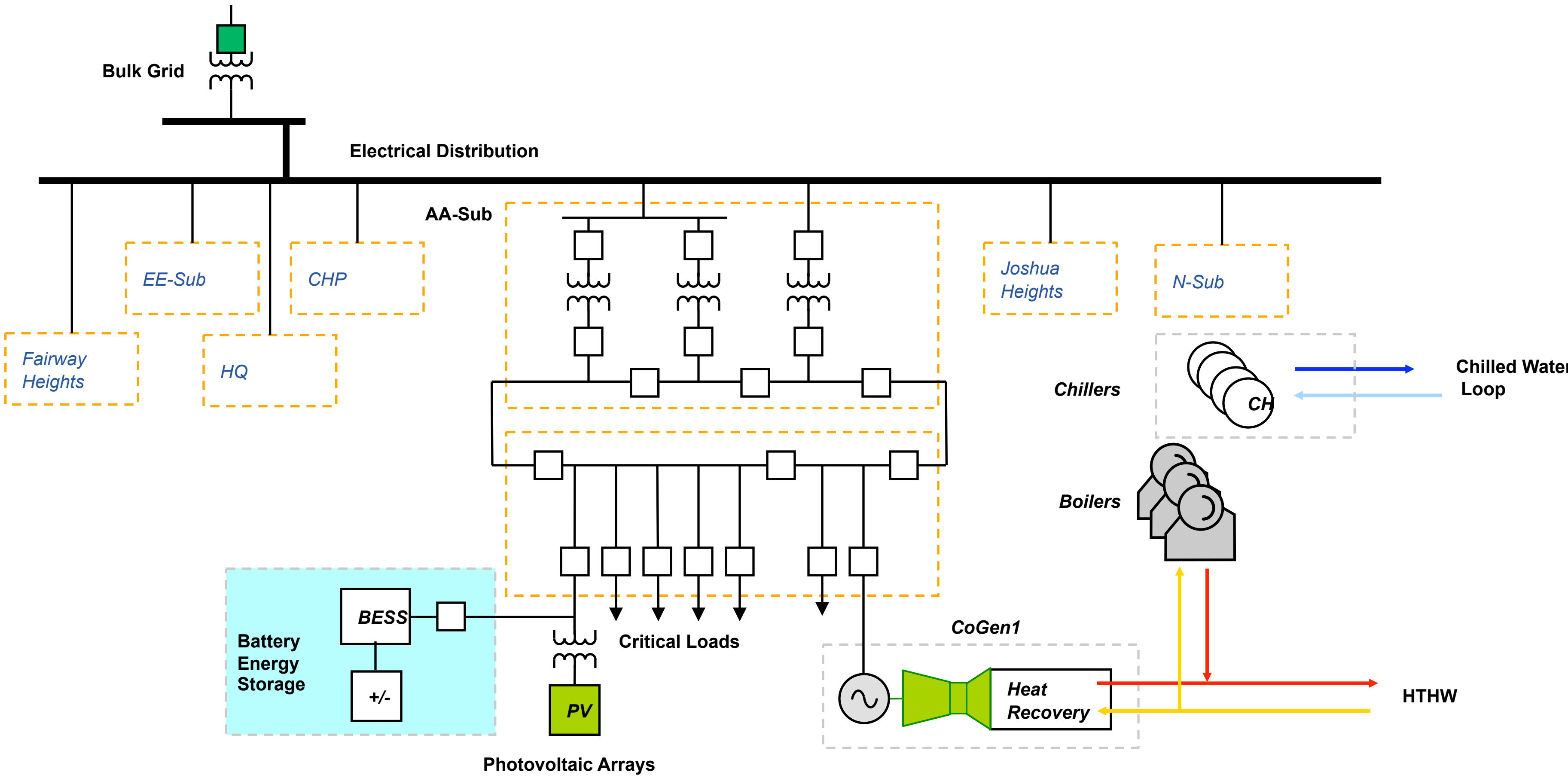
- Data-based scientific proof of the technical claims
- Collect Cost and environmental performance data to allow realistic estimates for full scale implementation

2. Transfer the technology

- Work with the intended DoD user community to achieve their acceptance and feedback on the usefulness of the technology

3. Provide data and support to achieve regulatory and end-user acceptance

29 Palms Microgrid



Phase 1: Technical Highlights

Advanced Energy Management for Distribution-based Resources:

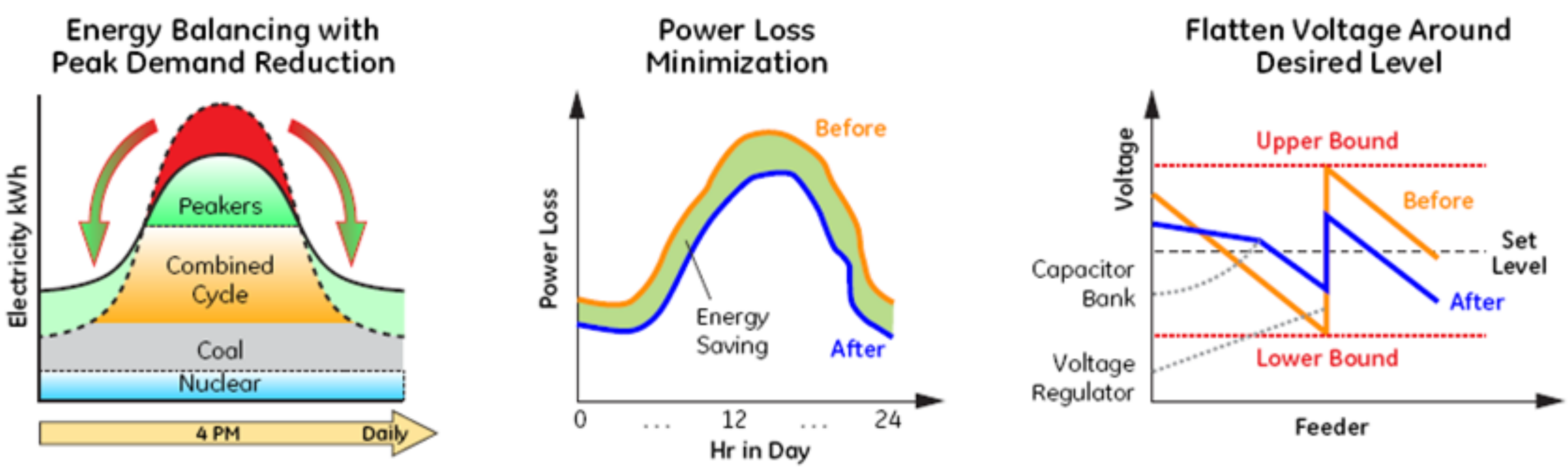
Completed all the following new features of microgrid:

- Optimal Dispatch of Distributed Energy Resources (DER) both during grid-connected and islanded conditions – development complete
- Dispatch capability of electrical and thermal assets - completed
- Built-in hooks of future enhancements like new CHP, new PV and energy storage (more things to optimize) - completed
- Interface of GE equipment with Legacy Systems from JCI, Rockwell etc.
- Testing in mixed type of communication media: wireless, Ethernet
- Testing Mixed type of protocols: Modbus, Bacnet, RSLinx
- Mixed mode of operations: Advisory, Automated, Manual and Legacy

Phase II – Integrated Volt/Var Control

The objective functions analyzed for application to military bases are:

- **Minimize peak load (through conservation voltage reduction)**
- **Minimize line power losses**
- **Minimize number of cap bank operations**
- **Voltage flattening**



Phase III – Battery Energy Storage System

Primary Technical Objectives:

- Increase Power Factor of Co-Generation facility
- Increase overall Solar Power Plant capacity factor, specifically during islanded operation
- Provide peak-shaving during high demand periods and reduce peak demand charges

Secondary Technical Objectives:

- Assess sodium-metal-halide energy storage technology in a grid-tied utility application.
- Develop and exercise algorithm's for
  - Voltage support
  - Frequency regulation
  - Low voltage ride through (LVRT)
  - Uninterruptable Power Supply (UPS) operation.

Questions?

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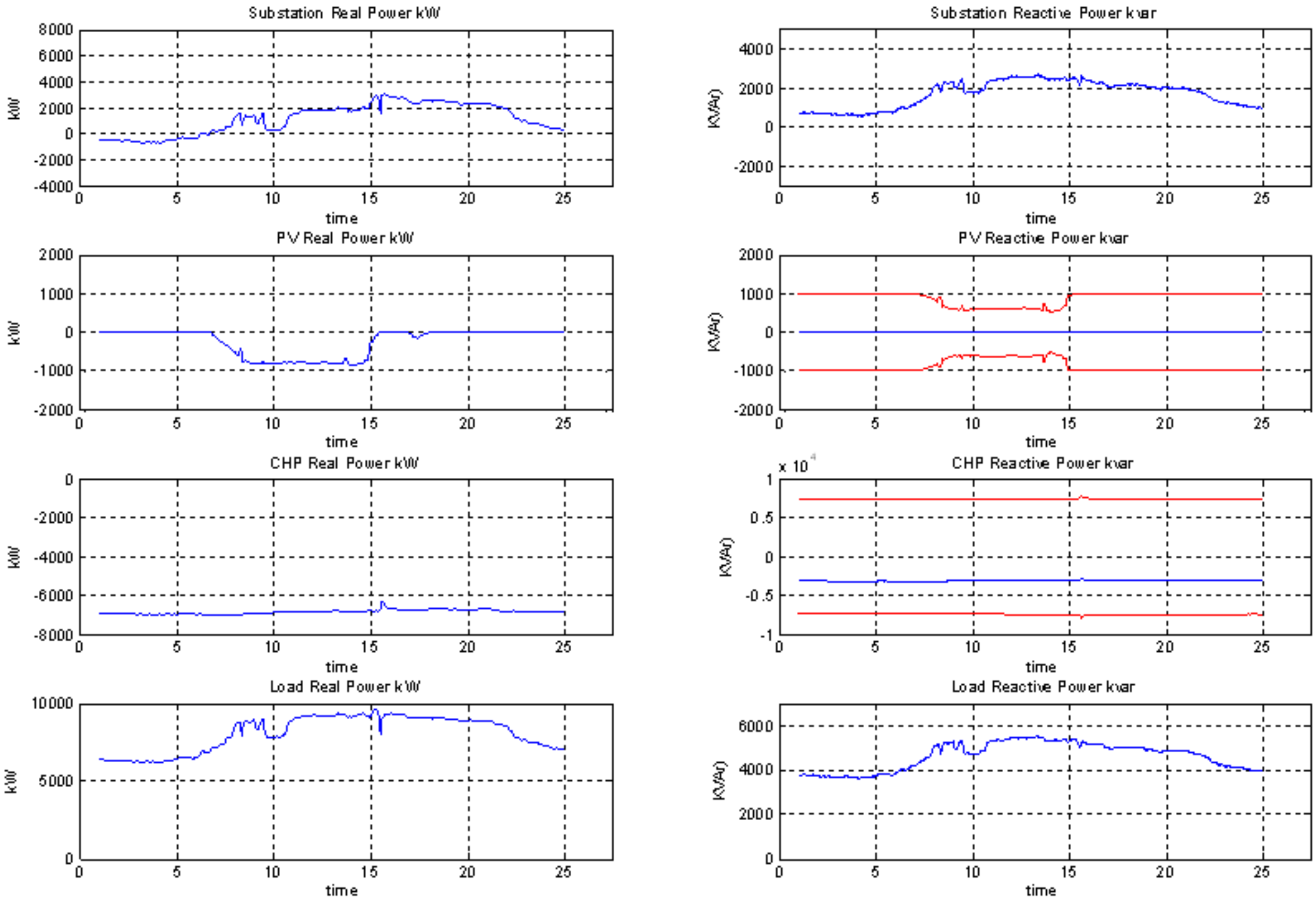
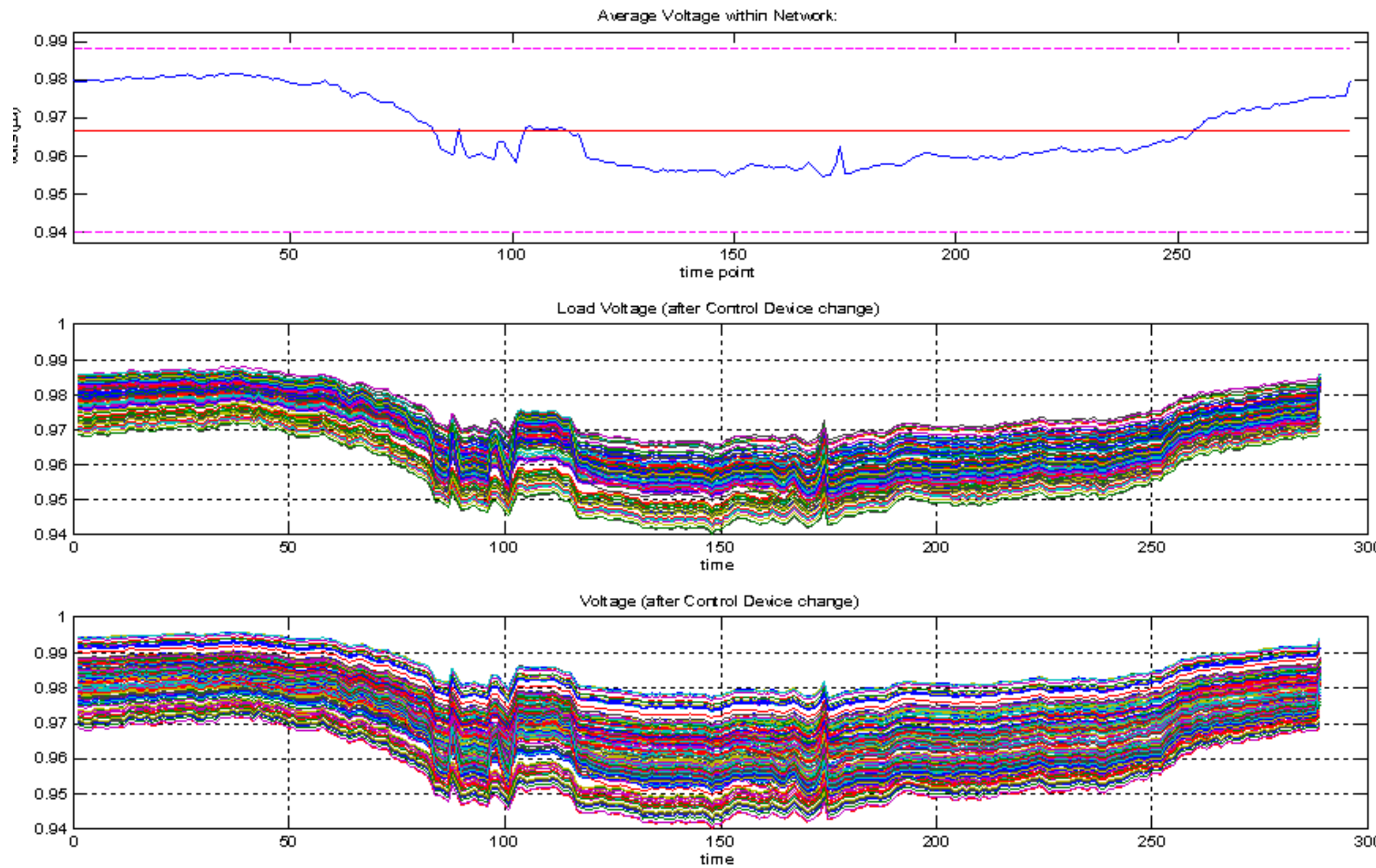
Appendix – Test Results

Baseline case powers (Jul 15 2010)



Baseline Q consumed from the grid 2000 kVar

Baseline case voltages (Jul 15 2010)



Number of min Volt violations: 87

Number of max Volt violations: 0

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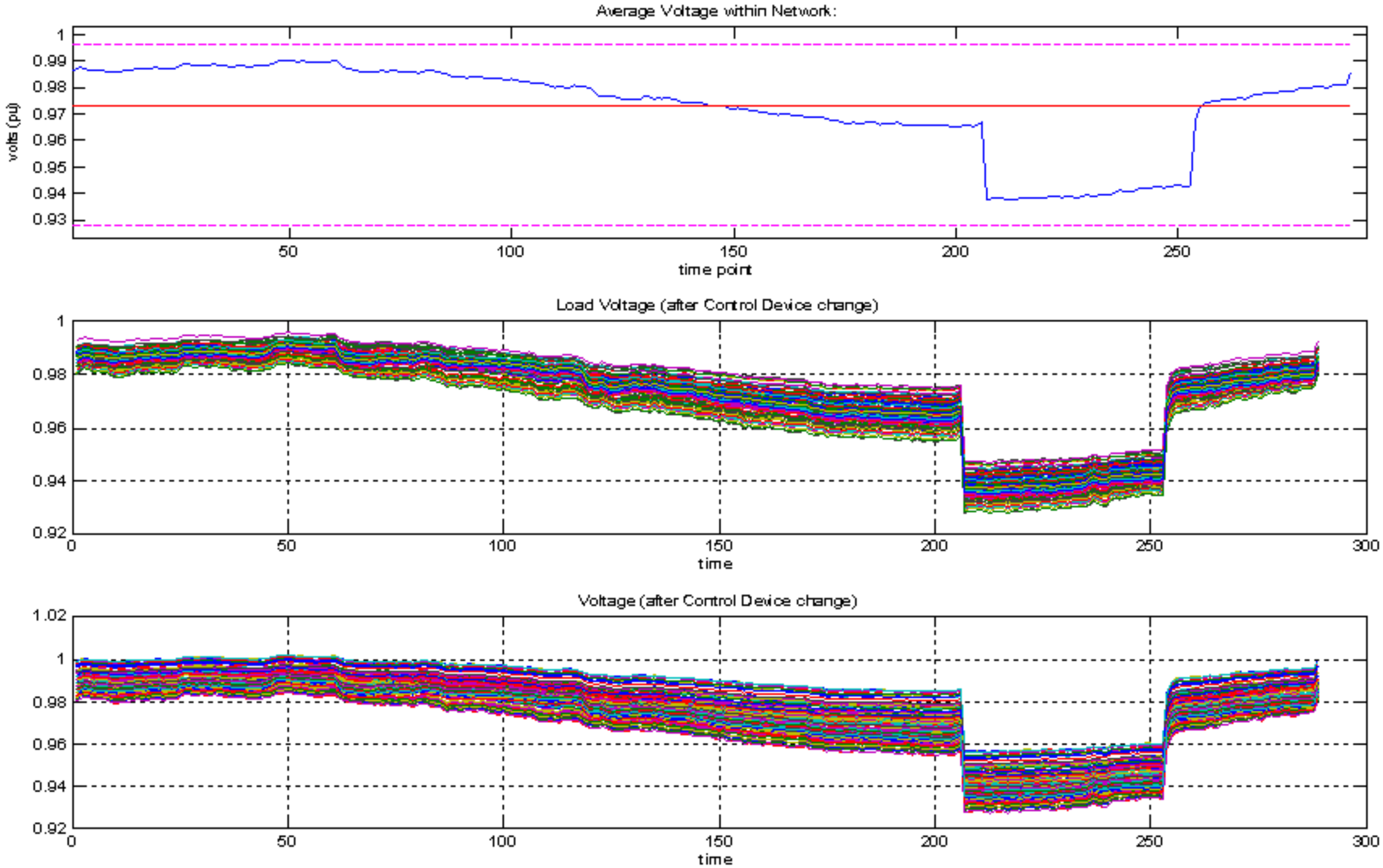
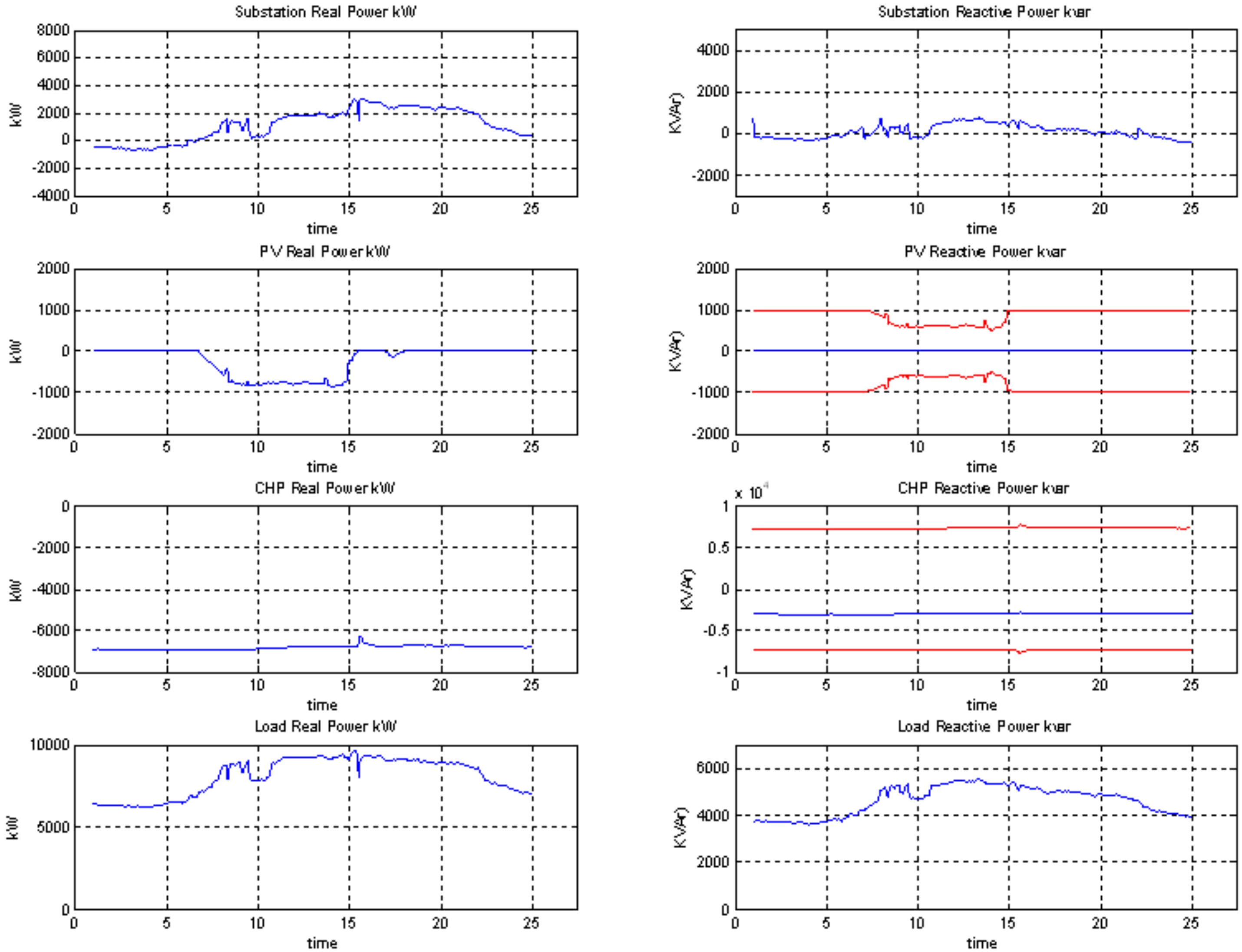
Baseline case Voltages (Aug 15 2010)



Number of min Volt violations: 1005

Number of max Volt violations: 0

DP results for Jul 15 2010



Peak Q consumed from grid reduced to 500 kVar

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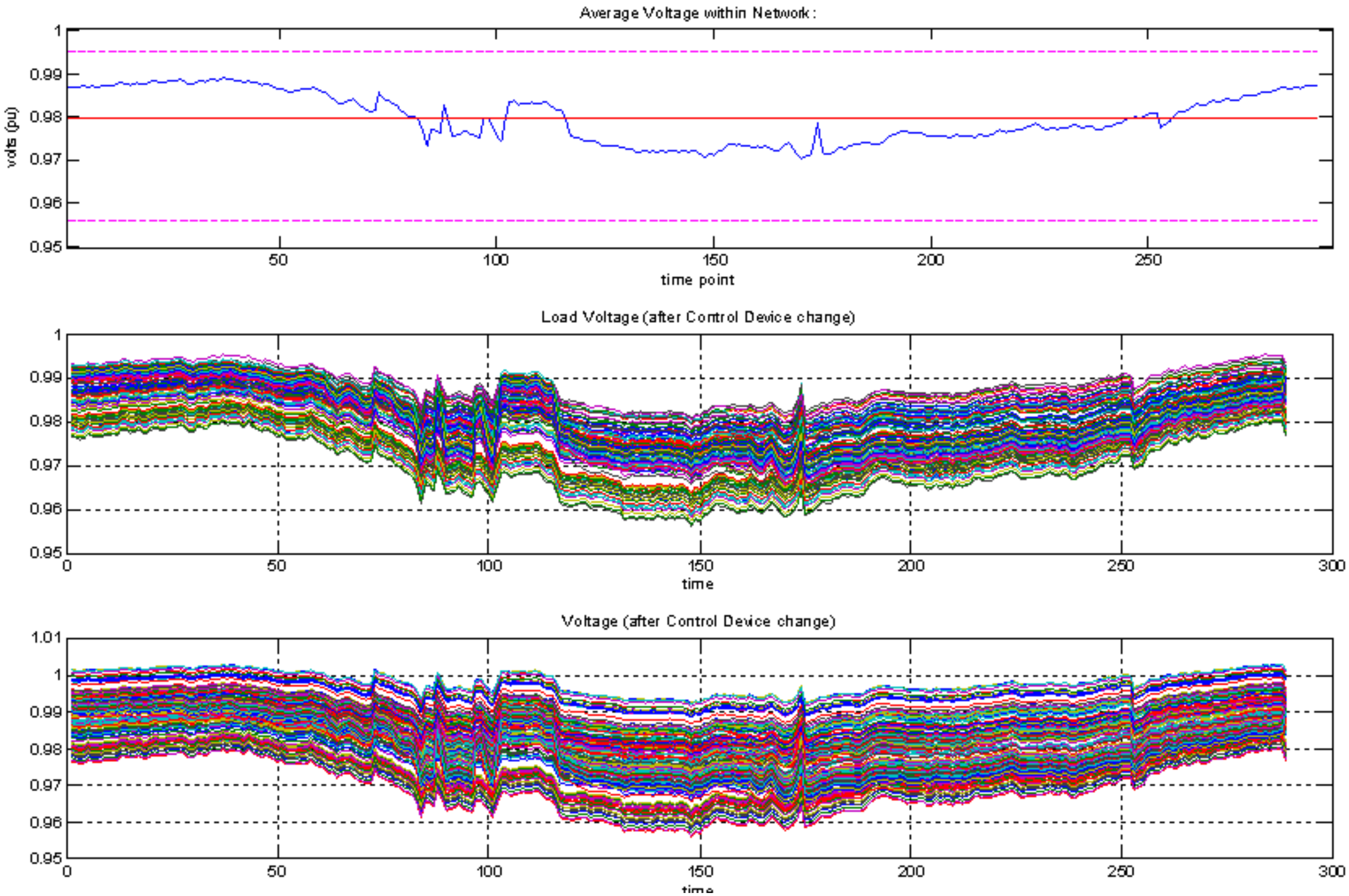
Results of DP on Voltages (Jul 15 2010)



Number of min Volt violations: 0

Number of max Volt violations: 0

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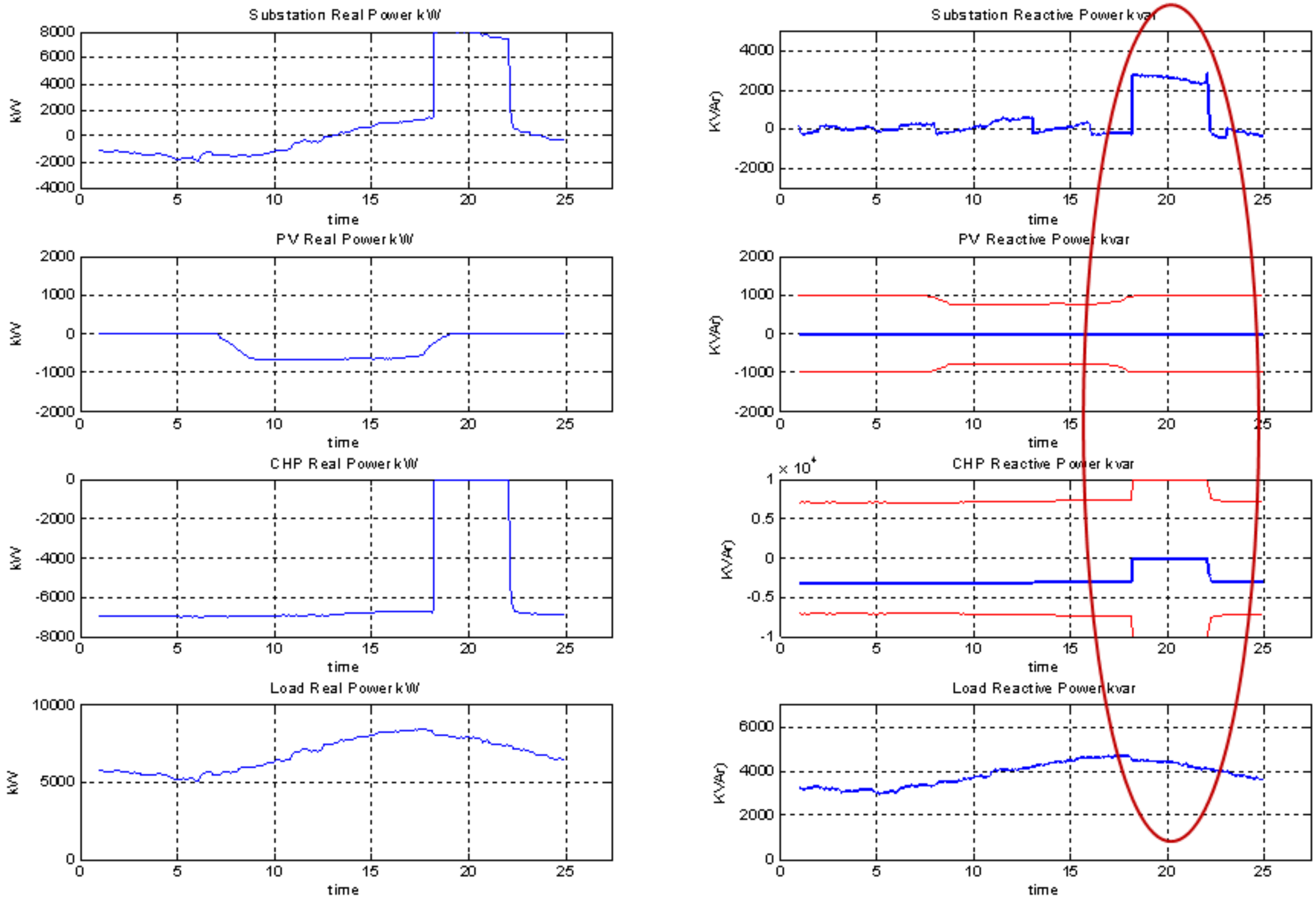
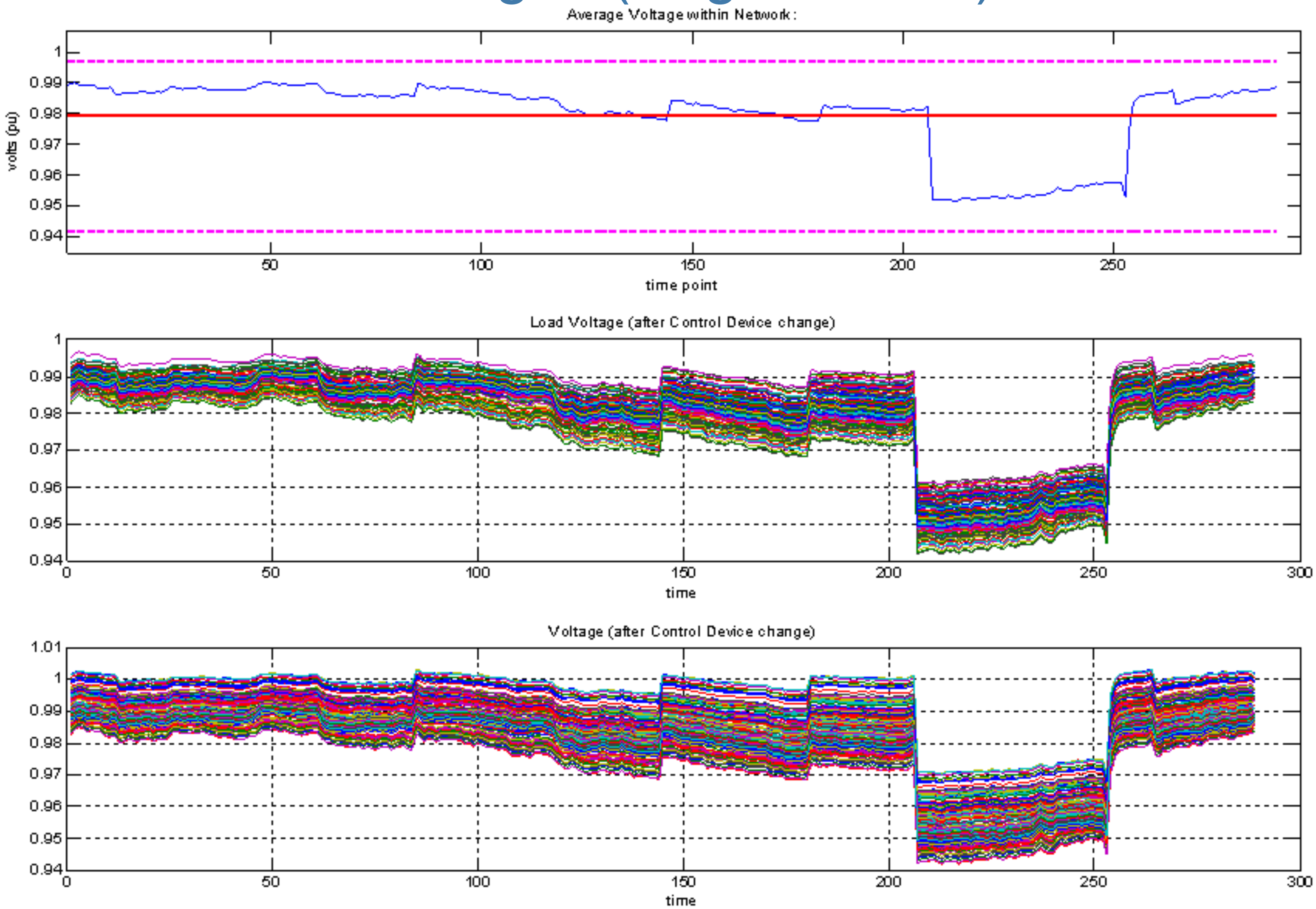
DP results for Aug 15 2010



Cap banks supplying half of Q during CHP loss

Results of DP on Voltages (Aug 15 2010)



Number of min Volt violations: 162

Number of max Volt violations: 0

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